Work Plan for Assessing Climate Change Impacts on California's Water Resources

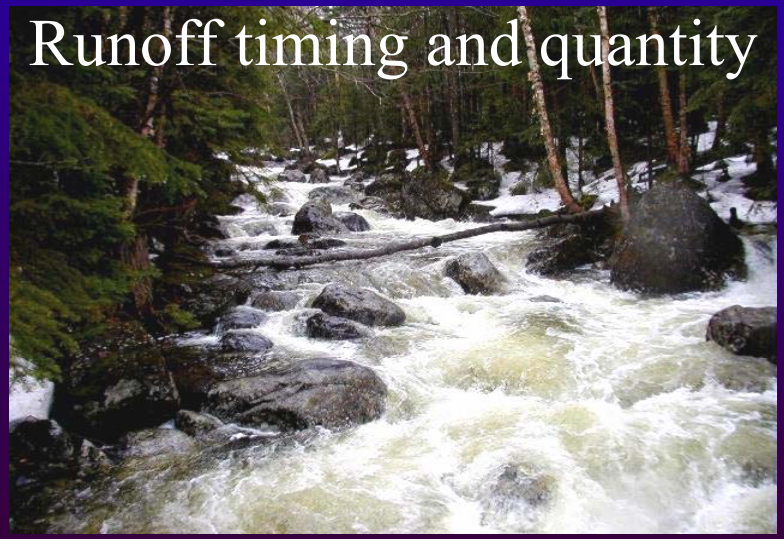
CWEMF Climate Change Workshop

November 21, 2003

Jamie Anderson, Ph.D., P.E.

Joint DWR-USBR
Climate Change Work Team

Potential Impacts of Climate Change



How could climate change affect management of California's water resources?

Floods and Droughts

- Rainfall intensity and durations
  redefine flood frequencies and flood zones
- Frequency, intensity and duration of droughts

Water Supply

- Water Demands
  human and vegetation

- Inflows to Reservoirs
  shift in peak timing and volume
- System Operations
  size and timing of flood control space

Water Quality

- Drinking WQ

- Environmental WQ
  River and lake temperatures
  In-stream flow requirements

San Francisco Bay-Delta

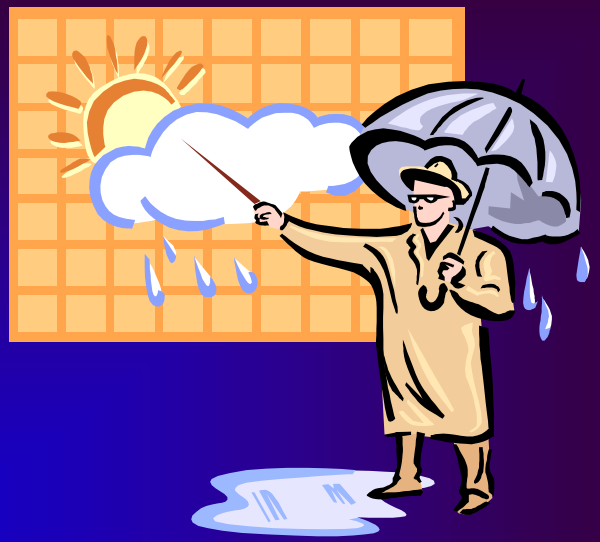
- Levee Stability
- Sea Water Intrusion: flow-salinity

GOAL

Provide qualitative and quantitative estimates of effects of climate change on California's water resources

Provide information that is relevant to water resources decision makers

Climate modelers forecast possible future climate conditions



Our climate change team assesses potential impacts that those climate change scenarios could have on California's water resources

Climate Change Information for Water Resources Managers

- Climate change hydrologies for planning studies
- Revised water supply reliability curves
- Changes in flood storage requirements
- Effects of sea level rise on water levels and water quality
- Provide input for the 2008 Water Plan update

Climate Change Work Team

- DWR Bay-Delta Office
  - Francis Chung, Ph.D., P.E.
  - Jamie Anderson, Ph.D., P.E.
  - Messele Ejeta, Ph.D., P.E.
- DWR Division of Planning and Local Assistance
  - Ganesh Pandey, Ph.D., P.E.
  - Sanjaya Seneviratne, M.S., P.E.
  - Brian (BG) Heiland, M.S., P.E.
- DWR Division of Environmental Services
  - Chris Enright, M.S., P.E.
  - Aaron Miller, P.E.
- USBR-MP700 Reservoir Systems Analysis
  - Levi Brekke, Ph.D., P.E.

Climate Change Work Team


Jamie Anderson


Sanjaya Seneviratne


Francis Chung


Levi Brekke


Messele Ejeta


Chris Enright


Aaron Miller


Ganesh Pandey

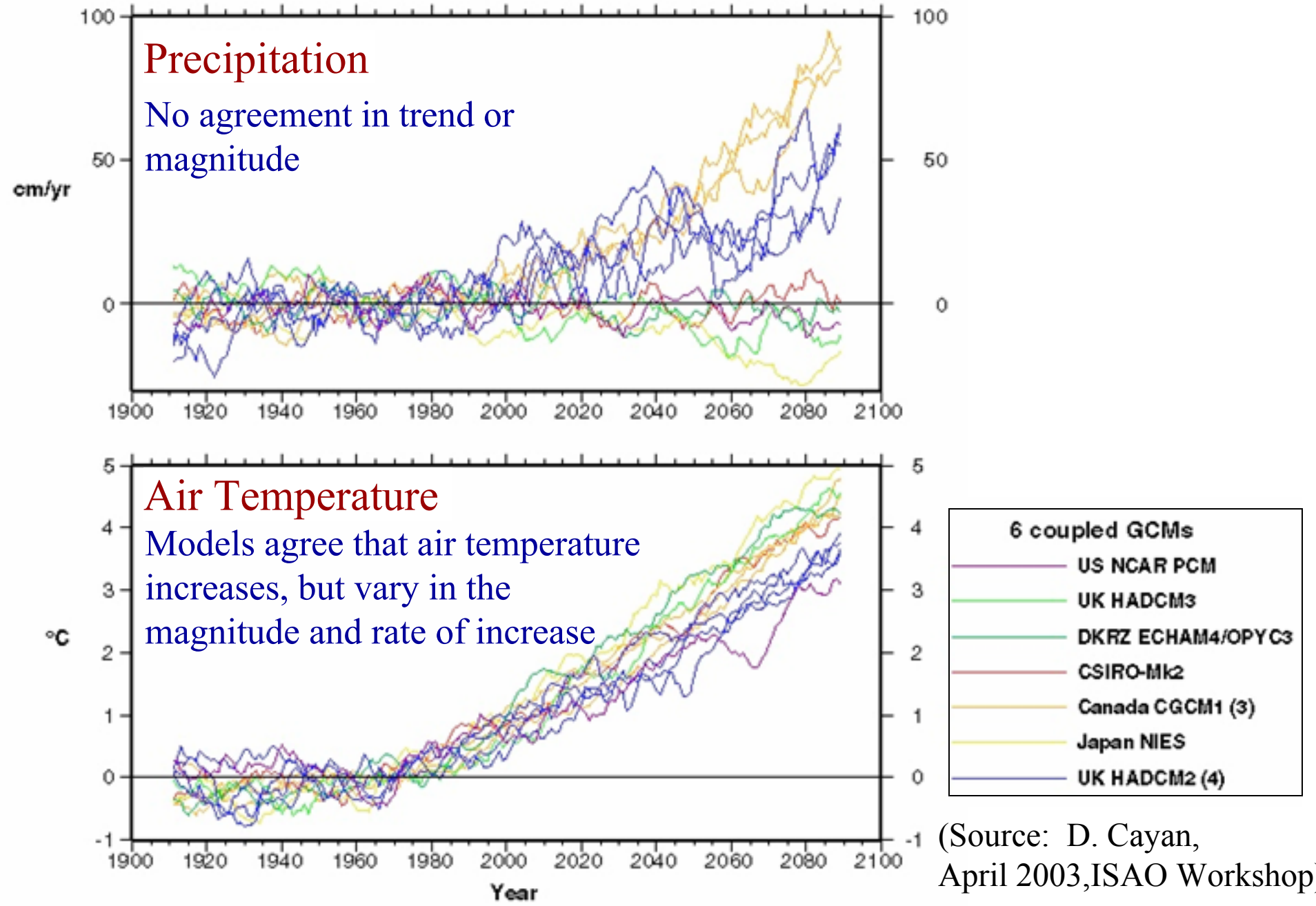

BG Heiland

Challenge

Given the variability and uncertainty in climate projections over California,

how do we apply climate change impacts assessment to planning and management of California's water resources?

Climate Change Predictions for Northern California Differ



(Source: D. Cayan, April 2003,ISAO Workshop)

Dealing with Climate Change Uncertainty

- Seek advice from other experts
- Develop/apply techniques for quantifying the uncertainty in climate change predictions
- Bookend approach
  - A lot warmer and wetter
  - A little bit warmer and drier
- Focus on predictions with least uncertainty
  - Increase air temperature only
  - Sea level rise

Potential Collaborators

California Energy Commission

Lawrence Berkeley Lab

DWR

Lawrence Livermore Lab

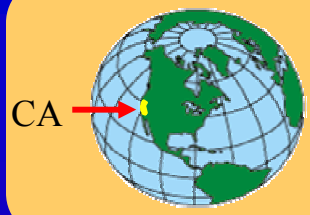
SCRIPPS Institute of Oceanography

U.S. Geological Survey

U.S. Bureau of Reclamation

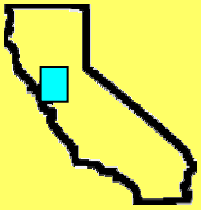
UC Davis Civil Engineering

Climate Team Work Plan



Select climate change scenarios

Investigate water supply impacts of hydrology changes



Investigate local impacts of sea level rise on the Delta

Assess combined impacts of changed hydrology and sea level rise

Sample Key Questions

- What would be the impacts of shifting timing and amount of precipitation and snow pack?
- How do recent regulatory regimes (e.g. B2 and EWA) affect water supply and reliability impacts in the face of climate change?
- What user groups are the most vulnerable to climate change?
- How would the constraints of current flood control practices affect water supply due to seasonal changes in hydrology?

Sample Key Questions

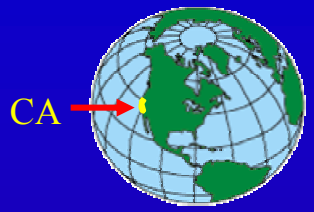
- How much fresh water would be required to mitigate for increased Delta salinity concentrations due to sea level rise?
- How do increased air temperatures affect Delta consumptive use?

Climate Team Work Plan

- Approaches
  - Simulation
  - Optimization
  - Sensitivity Analysis
  - Risk Analysis
- Potential Models/Tools
  - CALSIM II
  - DSM2
  - RMA-2 and RMA-11
  - G-Model
  - ANN
  - SIMETAW

Model Scales

Global Climate Models



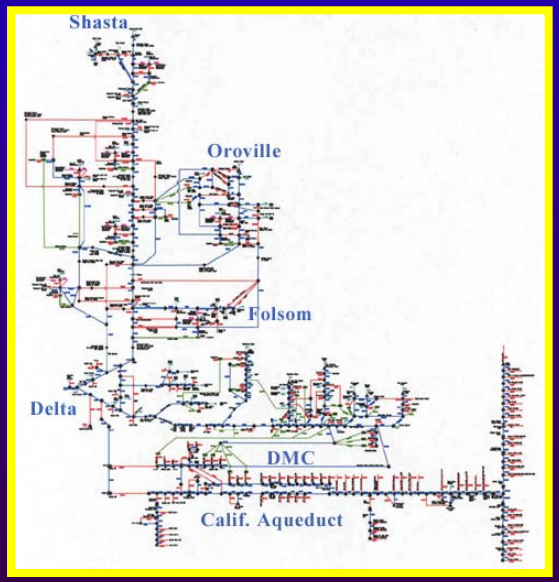
California is represented
by 1 to 6 points

500km grid

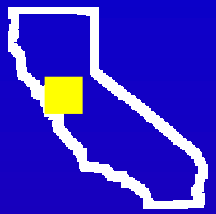
250km grid

CALSIM II

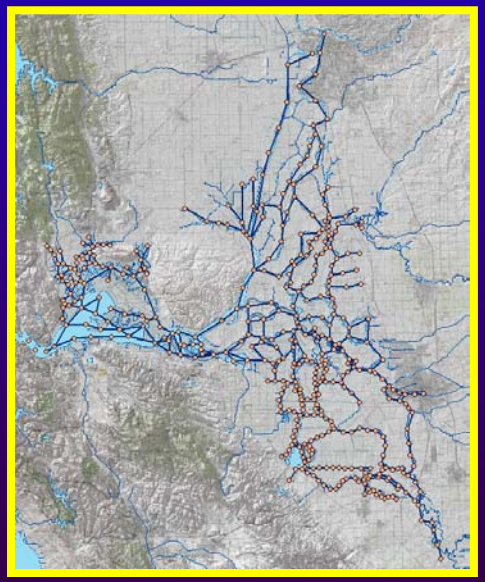
Central Valley represented
By ~300 points



DSM2 or RMA

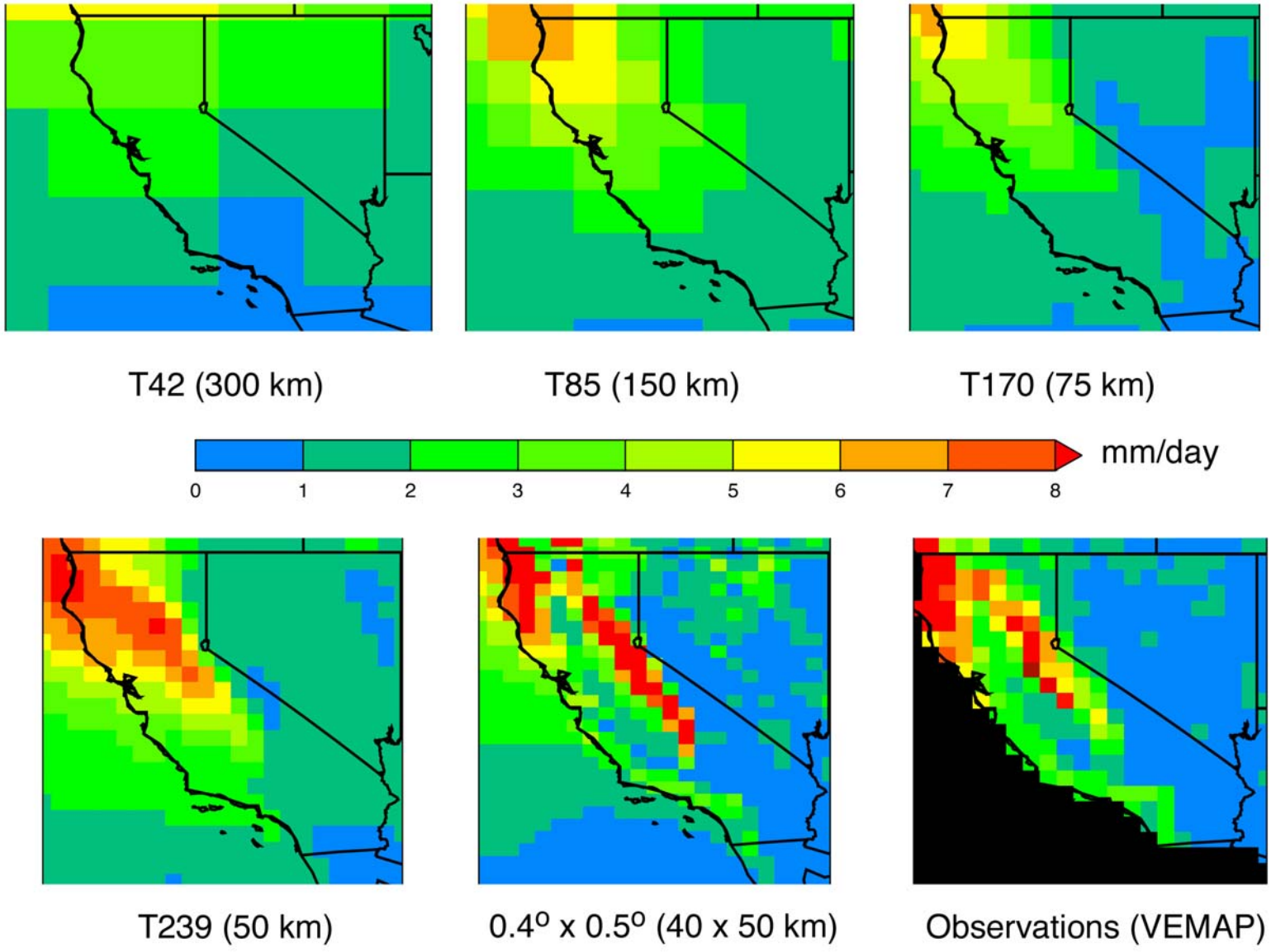


Delta is represented
by ~420 points



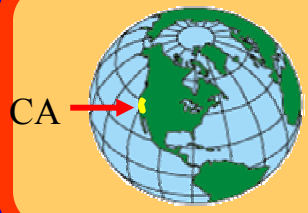
Spatial Resolution of Climate Change Scenarios

Simulated and observed precipitation patterns



Slide courtesy of Phil Duffy Atmospheric Science Division LLNL

Climate Team Work Plan



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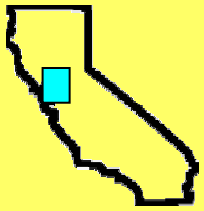
Investigate water supply impacts of hydrology changes



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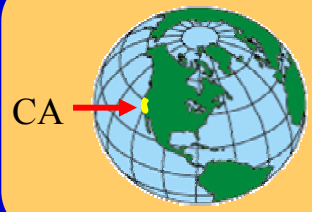
Assess combined impacts of changed hydrology and sea level rise

Select Climate Change Scenarios



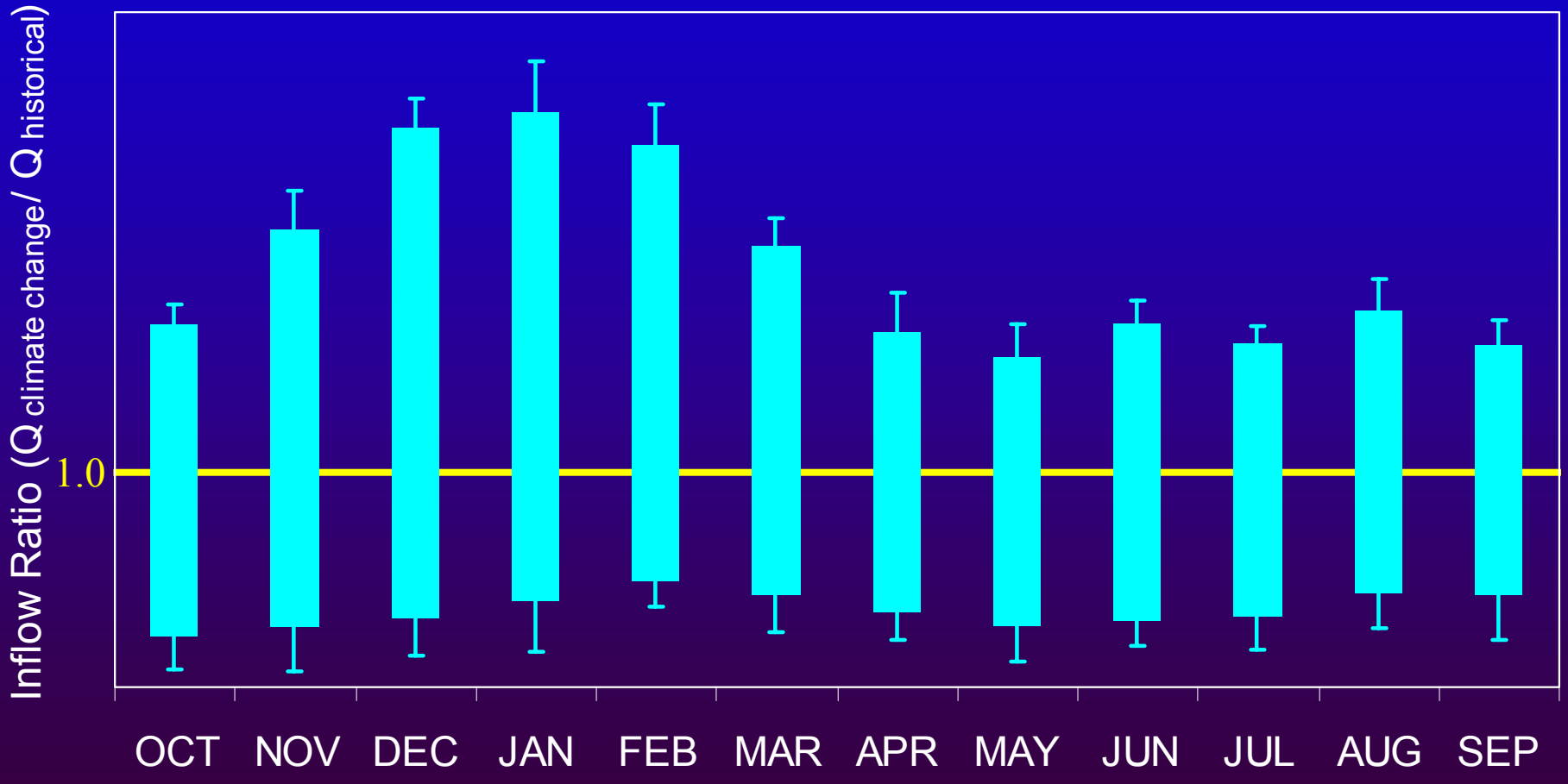
- Climate change scenarios from GCMs
  - Perturbations applied to historical data
  - Downscaled data
  - Fine scale GCM
- Selecting climate change scenarios
  - Uncertainty analysis for air temp, precip, and runoff
  - Bookend scenarios
  - Scenarios with less uncertainty
    - Increase air temperature only
    - Sea level rise

Uncertainty Analysis for Climate Change Results

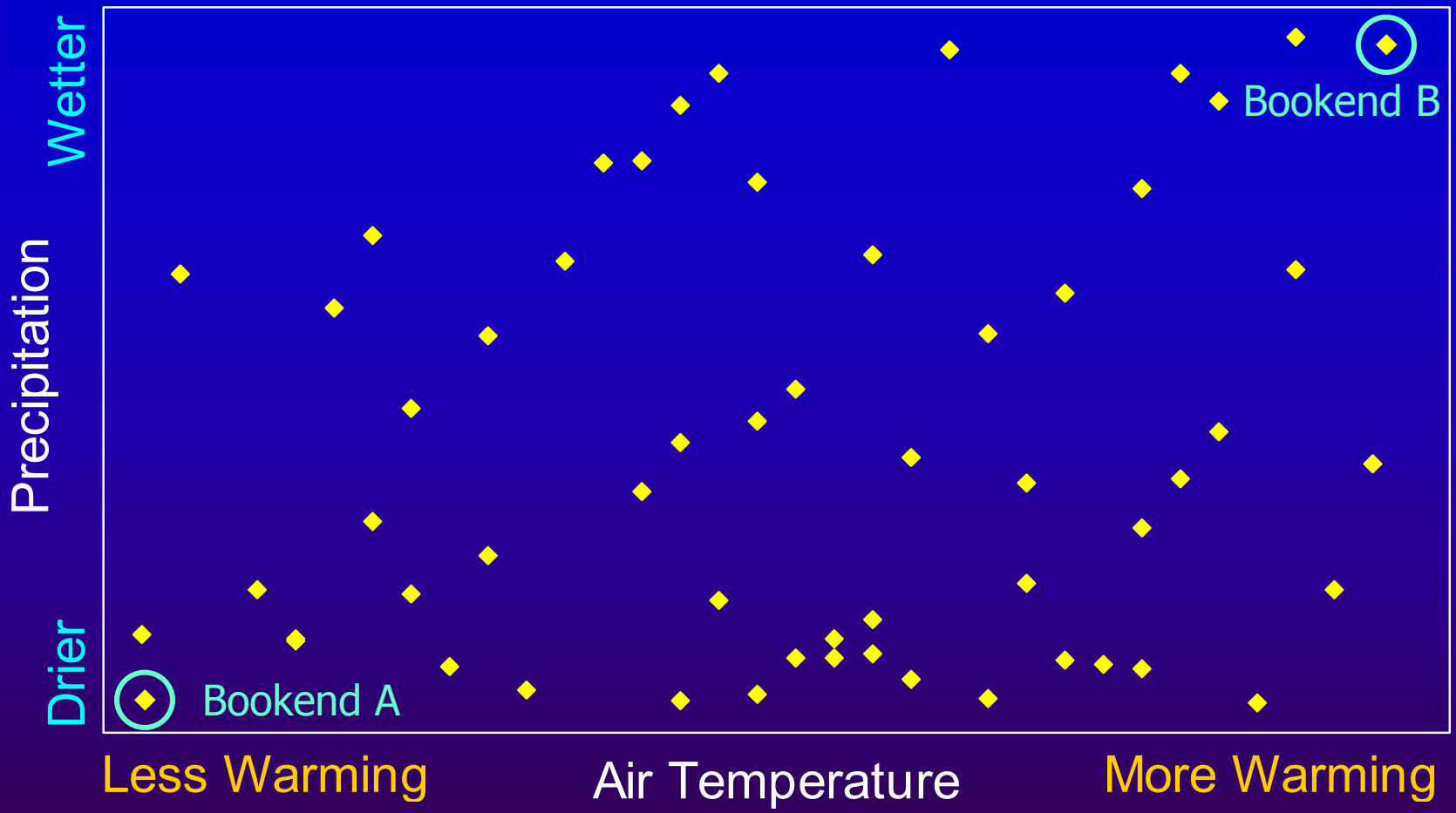
- Develop monthly sensitivity patterns for:
  - Air temperature
  - Precipitation
  - Natural runoff
- Watershed scales (e.g. Oroville, Shasta, etc)
- Evaluated at projection milestones (e.g. 25 years out, 50 years out)
- Account for projection uncertainty:
  - Patterns from multiple CO_2 increase scenarios and/or multiple GCMs of each CO_2 scenario

Conceptualization of Uncertainty

Probability bands for inflow into a given reservoir at a specific projection (e.g. Oroville 25 years into the future)

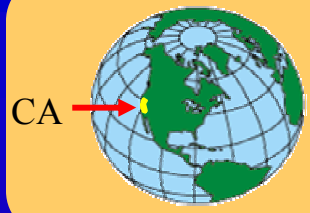


Bookend Approach



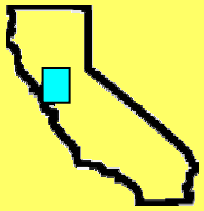
Bookend approach is used to identify ranges of potential impacts. Additional analysis would be required to identify mitigation measures.

Climate Team Work Plan



Select climate change scenarios

Investigate water supply impacts of hydrology changes



Investigate local impacts of sea level rise on the Delta

Assess combined impacts of changed hydrology and sea level rise

Investigate water supply impacts of hydrology changes

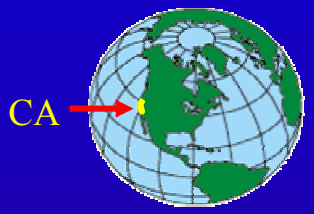
- Shifts in timing and/or amount of precipitation and snow pack (CALSIM II, CAM, etc)
  - Deliveries
  - Releases
  - Storage
- Changes in consumptive use of water due to changes in air temperature (SIMETAW)

Initial Climate Change Hydrology Study

- Extend climate change study by Brekke et al.
- Original study
  - Bookend study using PCM and HadCM2
  - 1% per year increase in "effective CO_2"
  - Shift inflow hydrology into CALSIM II using monthly perturbations from GCM results
  - D1641 at 2001 level of development
- Extended study
  - Use bookends (PCM and HadCM2)
  - Increase in air temperature with historical precip
  - D1641 at 2020 level of development
  - D1641-B2-EWA at 2020 level of development

CALSIM II Studies for Climate Change

Global Climate Models



Monthly Inflow Perturbations

Input

Emissions Scenario

Output

- Precipitation
- Snowmelt
- Air Temperature
- Evapotranspiration
- Soil Moisture

CALSIM II

Input

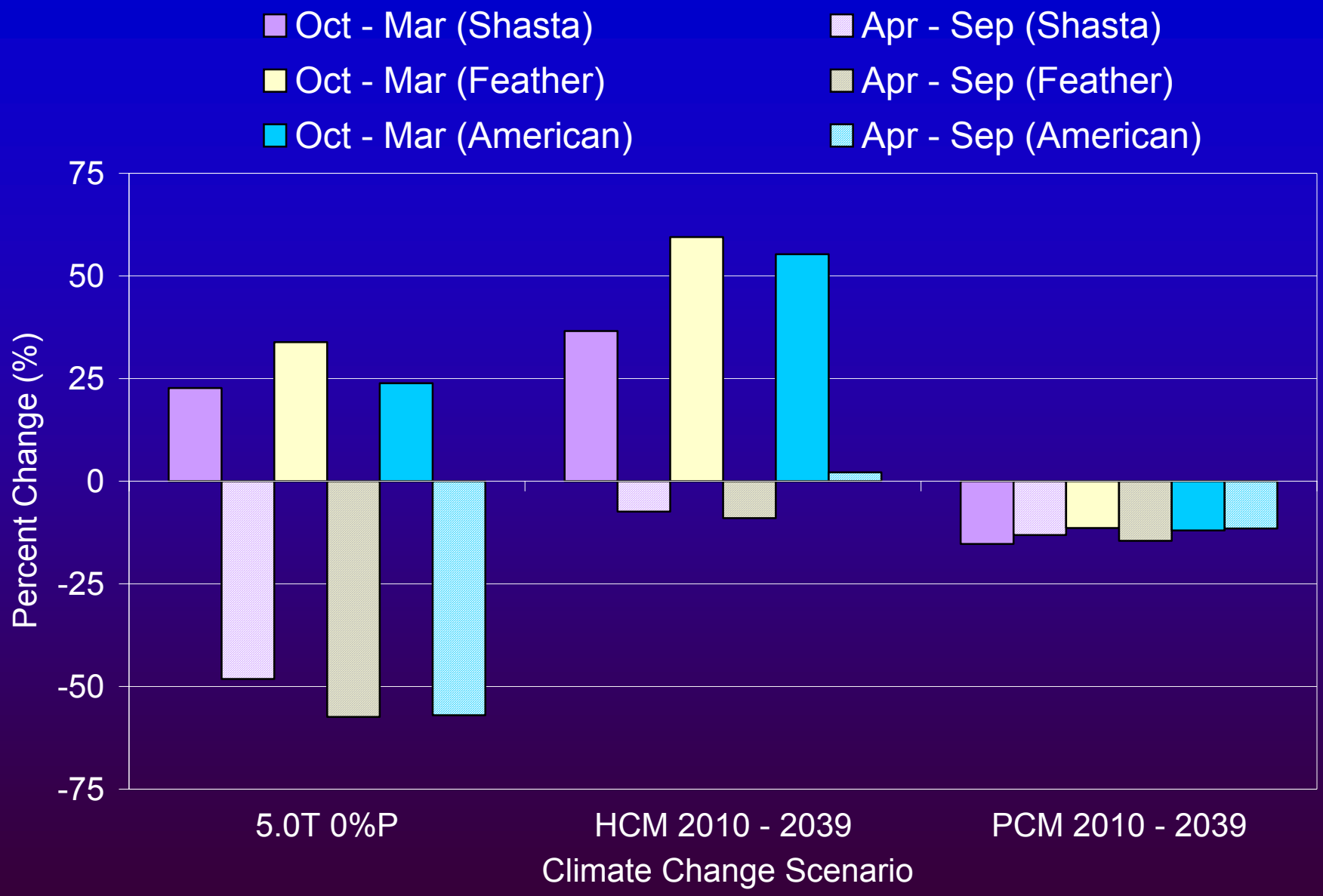
Modify inflows for 1922-1994 by perturbations from GCMs

Output

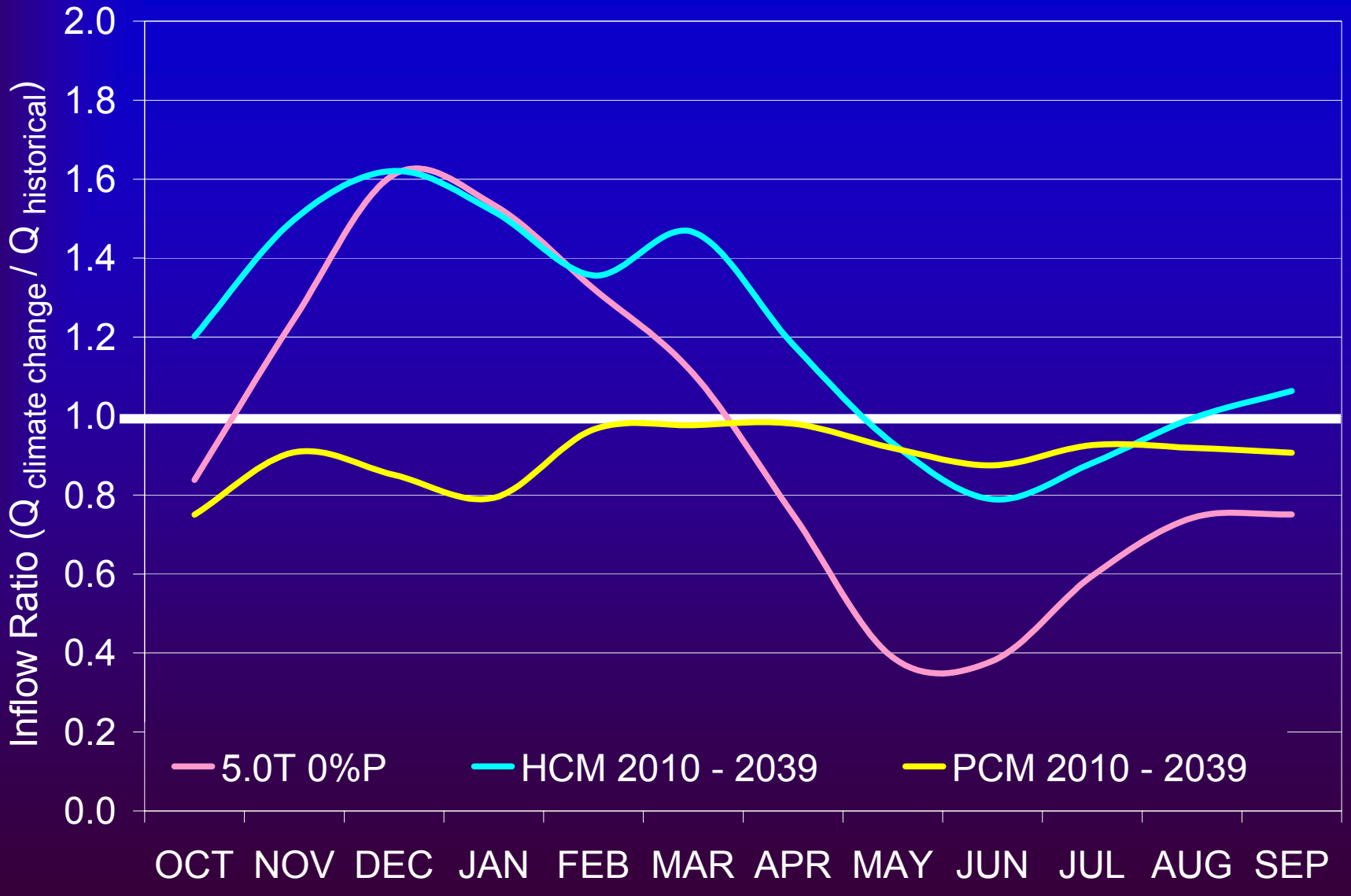
- Reservoir releases
- Reservoir storage levels
- Project deliveries
- Delta inflows and exports

Monthly inflow perturbations from Miller et al., JAWRA 2003

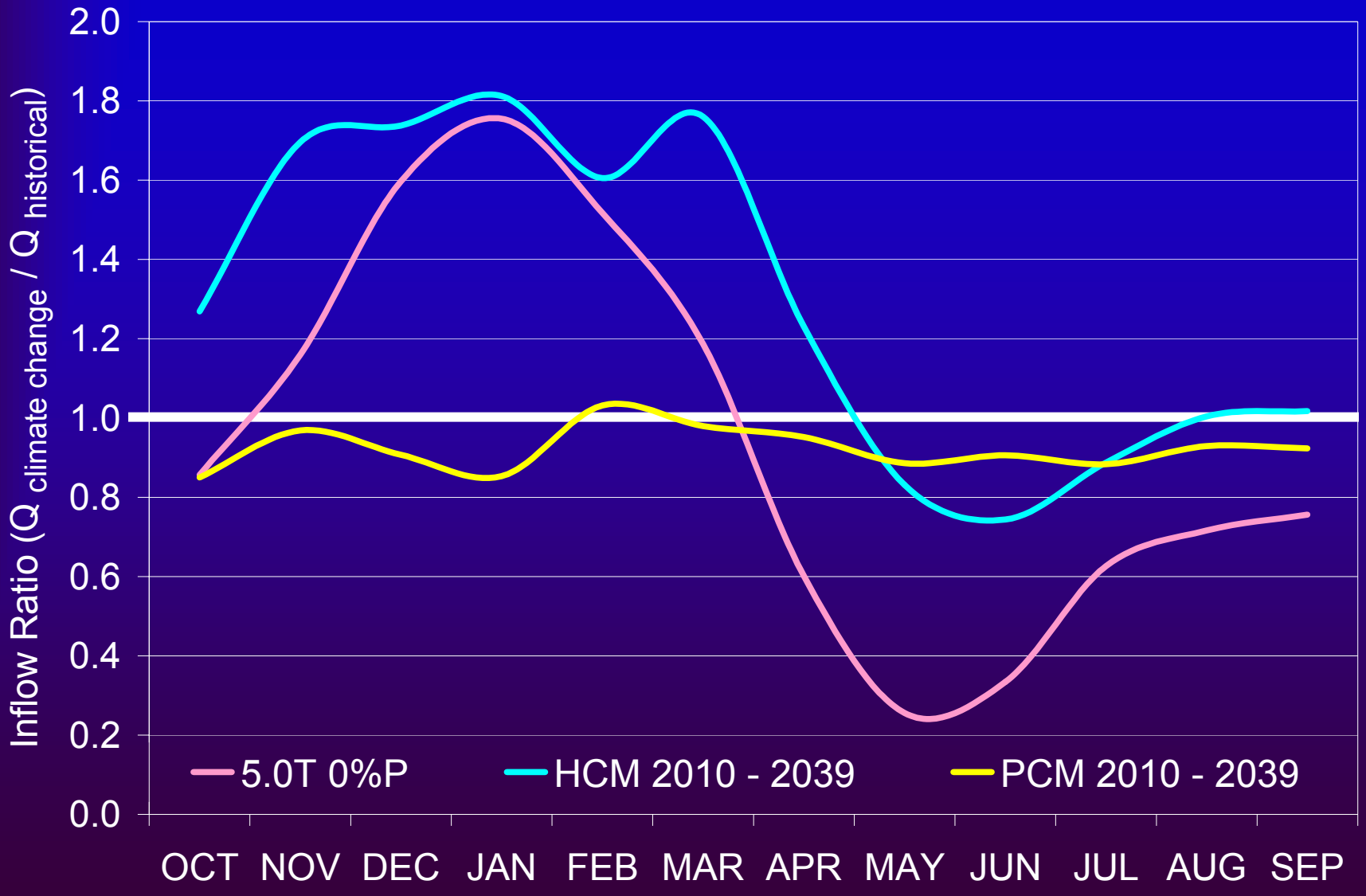
Average Seasonal Percent Change of Index Basin Runoff Compared with Historical Data (1963-1992)



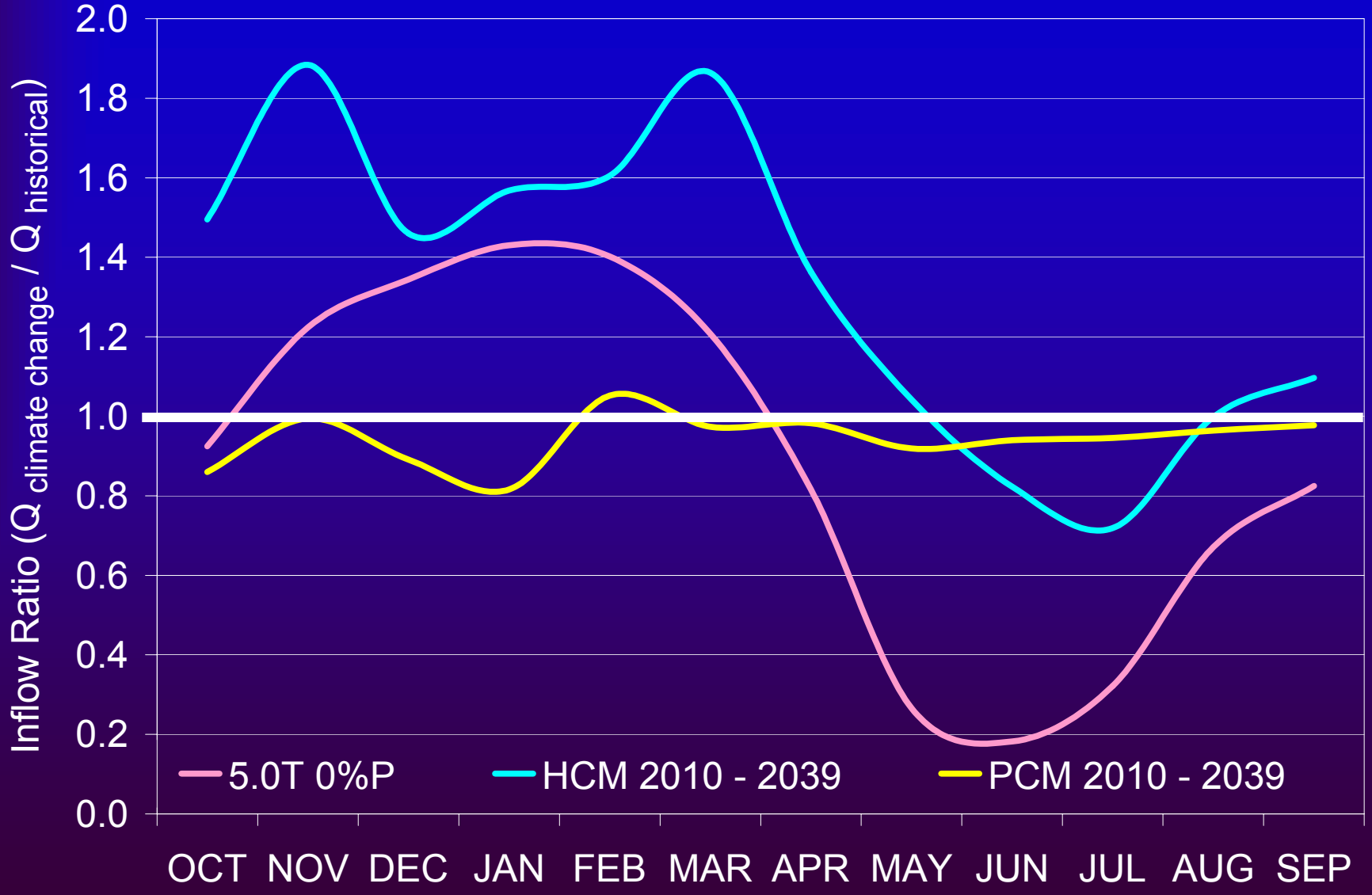
Shasta Monthly Inflow Ratios



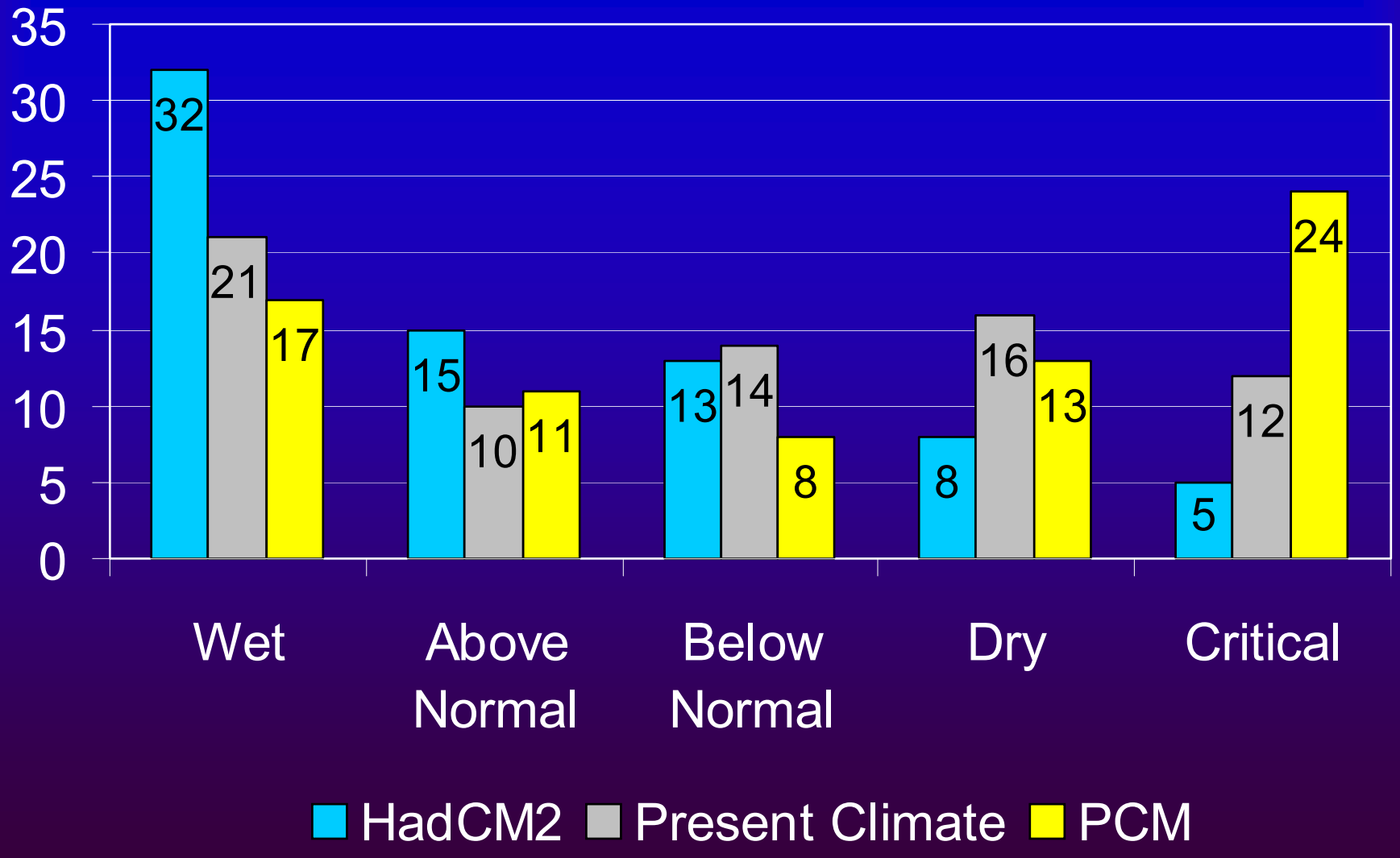
Oroville Monthly Inflow Ratios



Folsom Monthly Inflow Ratios



Modify Water Year Types

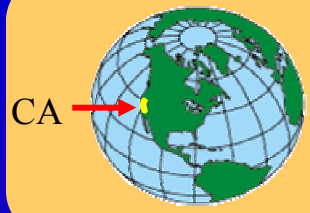


Analysis of CALSIM II Climate Change Results

- Changes in system operations
  - Reservoir releases
  - Reservoir storage levels
  - Project deliveries
  - Delta inflows and exports
- Identify vulnerable components of the system
- Delivery reliability curves for climate change
- Changes in X2 (habitat and WQ measure)

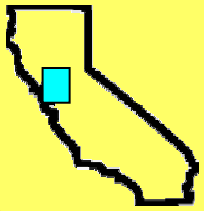
X2 is the location in the Bay-Delta of 2 ppt salinity

Climate Team Work Plan



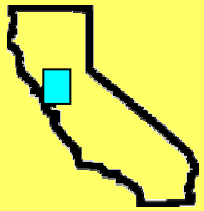
Select climate change scenarios

Investigate water supply impacts of hydrology changes



Investigate local impacts of sea level rise on the Delta

Assess combined impacts of changed hydrology and sea level rise



Investigate local impacts of sea level rise on the Delta

- Changes in Delta water quality
- Potential effects on levee stability
- Modifications to sensitive brackish habitat
- Relative risk of changes due to sea level rise compared to variability due to other sources

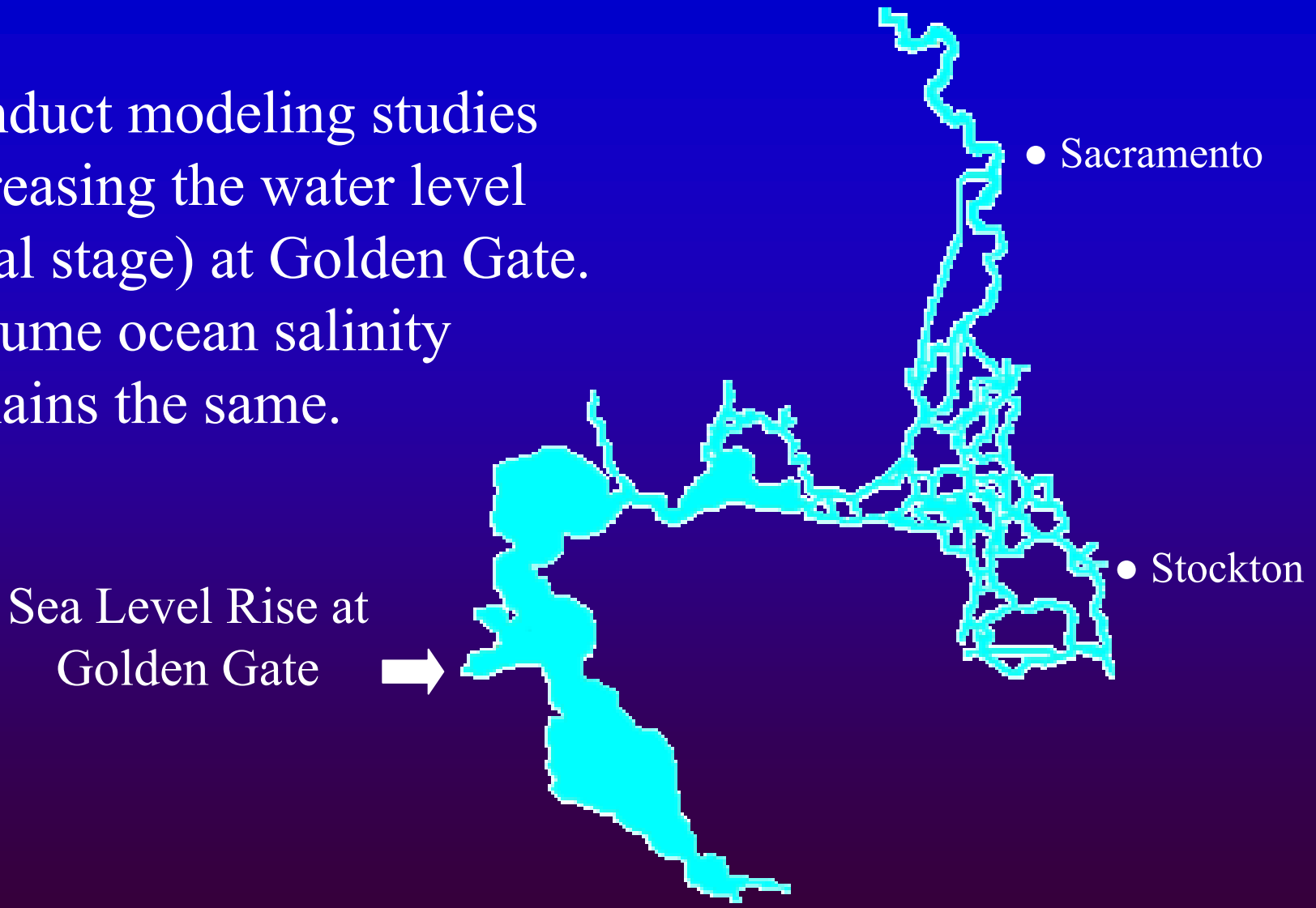
Causes of Sea Level Rise

Thermal expansion of the ocean

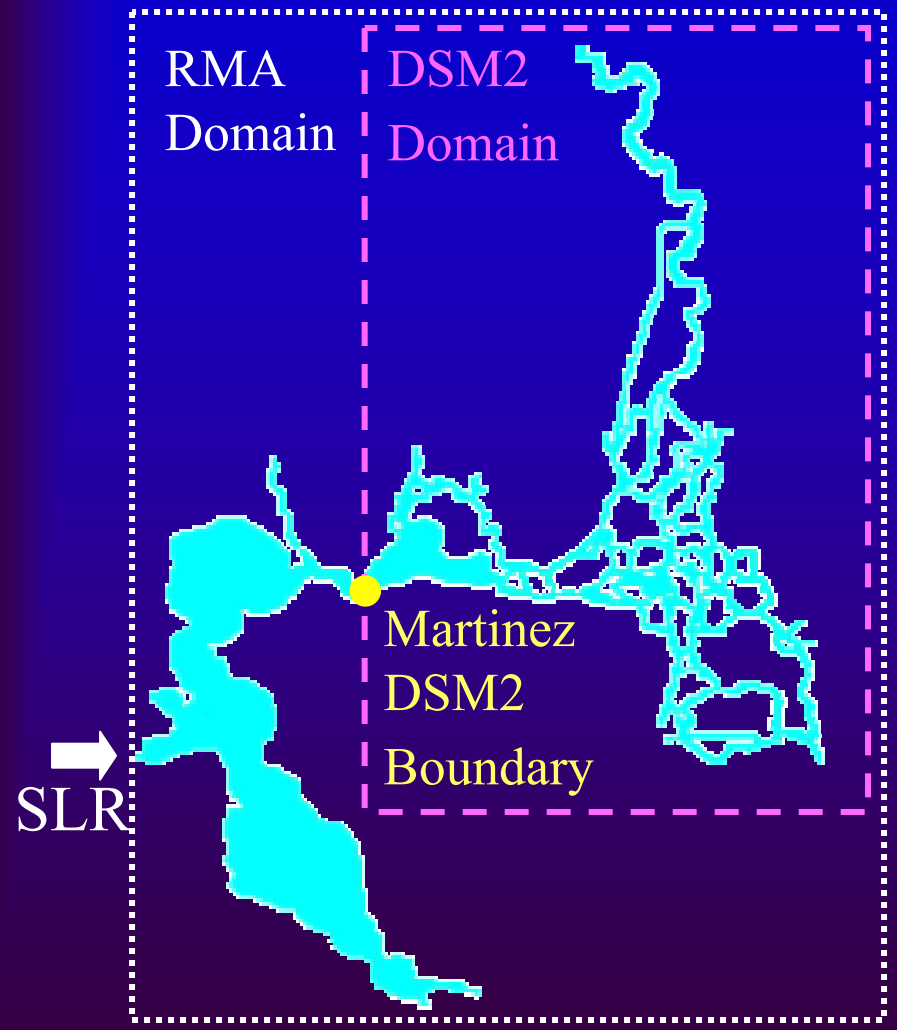
Melting of polar ice caps

How much water and salt would be transported into the Delta with sea level rise?

Conduct modeling studies increasing the water level (tidal stage) at Golden Gate. Assume ocean salinity remains the same.



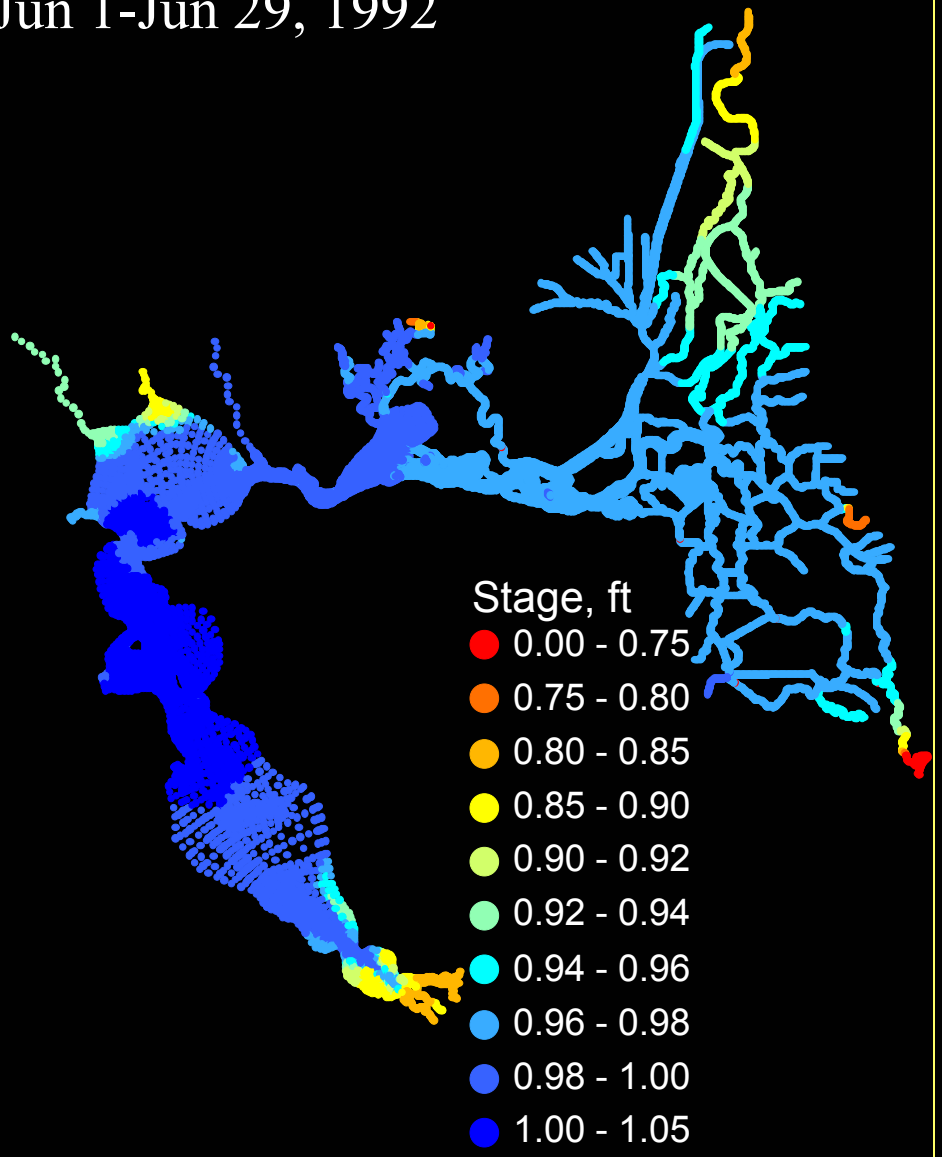
SLR Modeling Approach



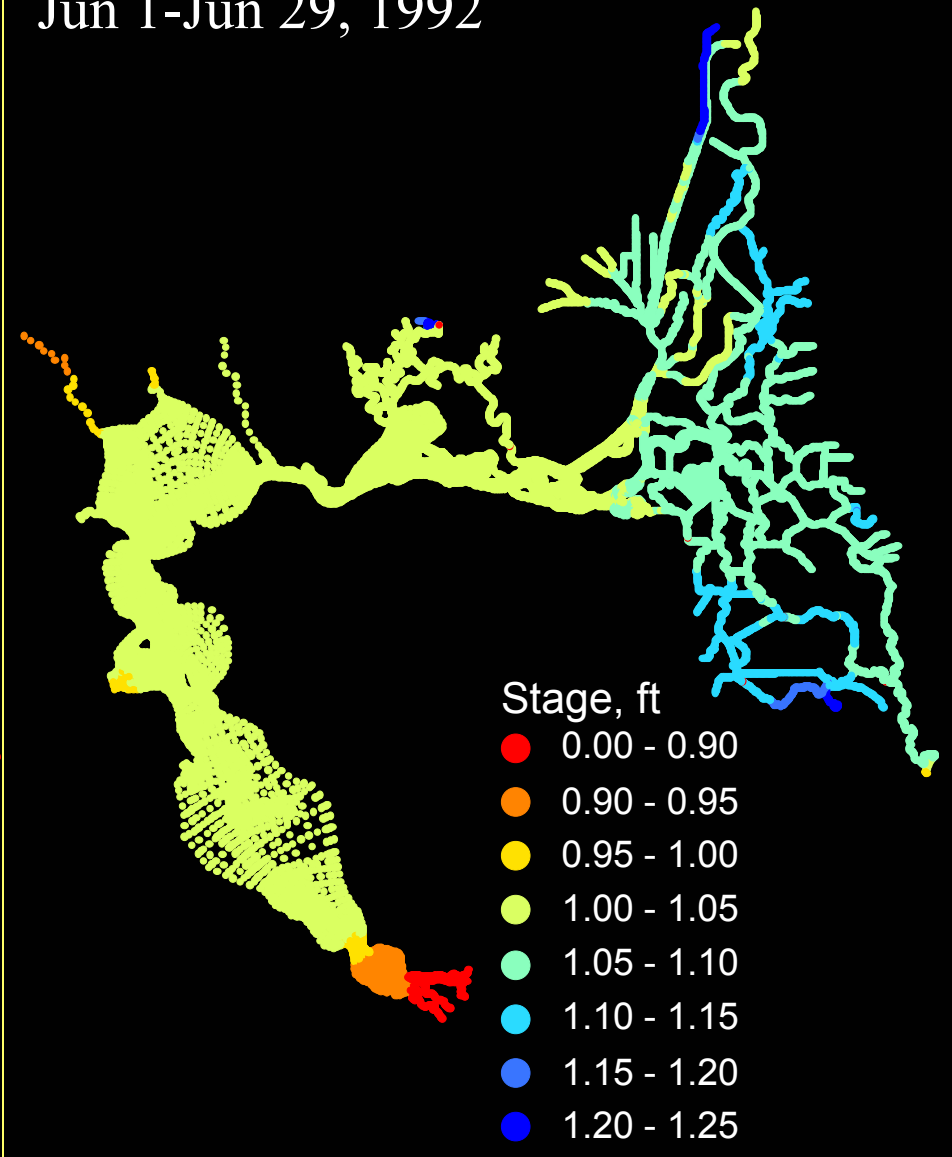
- Use multi-dimensional RMA models for short term detailed studies Jan 1-June 30, 1992
- Develop SLR EC relationships at Martinez (G-model, ANN)
- Run DSM2 for longer term SLR studies (1976-1991)

Preliminary Simulated Changes in Water Levels

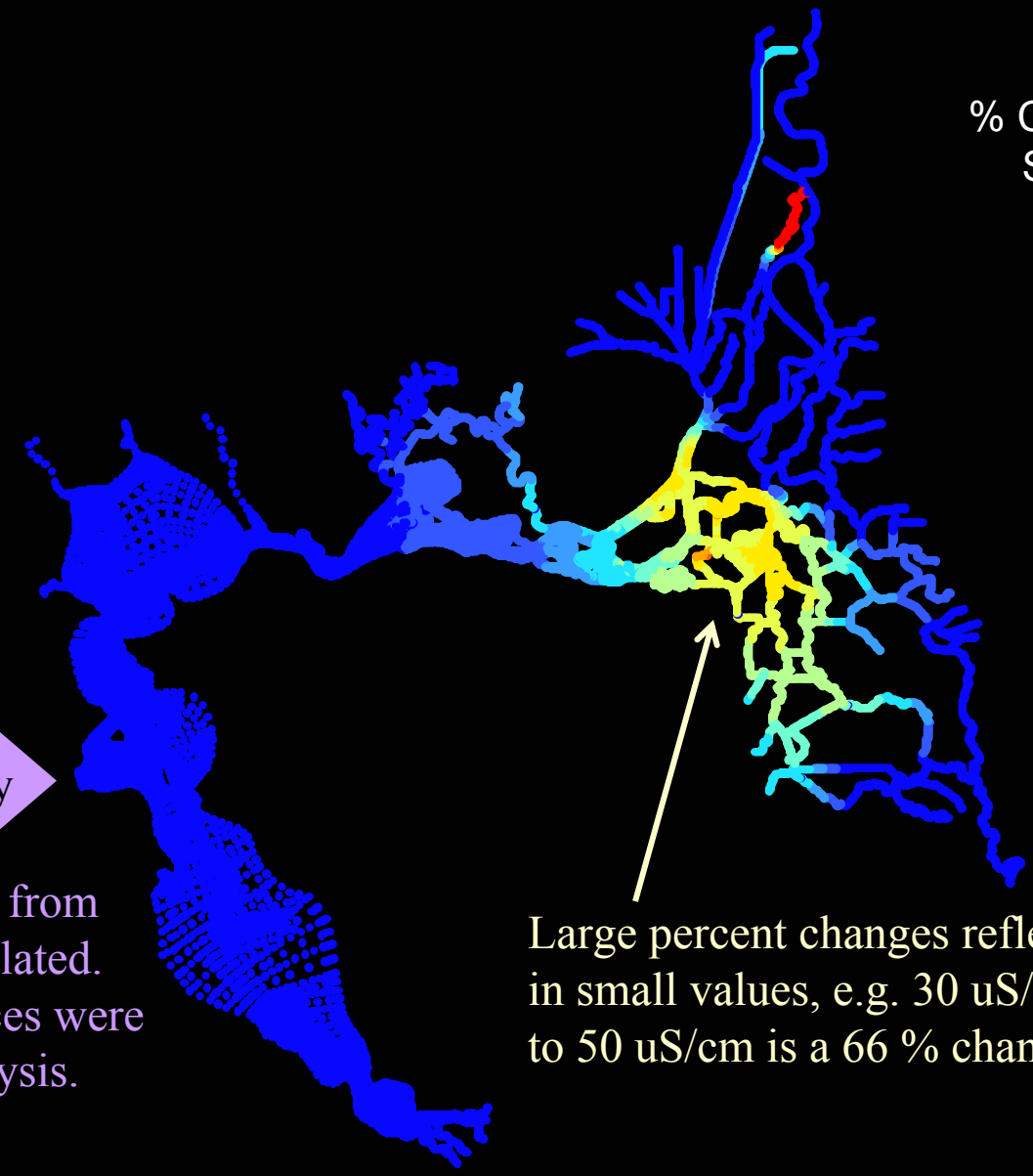
Diff Avg Stage SLR=1ft minus Base
Jun 1-Jun 29, 1992



Diff Max Stage SLR=1ft minus Base
Jun 1-Jun 29, 1992



Preliminary Simulated Changes in Salinity Intrusion



Only salinity intrusion from Golden Gate was simulated. No other salinity sources were considered in this analysis.

Large percent changes reflect increases in small values, e.g. 30 uS/cm increasing to 50 uS/cm is a 66 % change.

Analysis of SLR Results

- Quantify changes in
  - Tidal phase
  - Water levels (levee stability, barrier ops, habitat)
  - Salinity (water quality, habitat)
- Identify mitigation measures
  - Increase fresh water releases
  - Modify pumping patterns
  - Increase levee heights

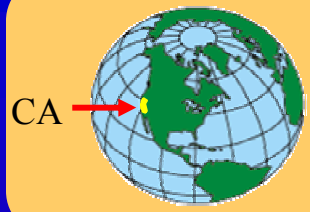
Analysis of SLR Results (cont.)

- Identify mechanisms behind changes
  - Shear flow dispersion
  - Tidal pumping
  - Tidal trapping
- Relative risk of changes due to sea level rise compared to variability due to
  - Tidal fluctuations
  - Stage changes due to low pressure systems
  - Changes in system inflows and exports

Characterize SLR EC Relationships

- Develop representations of EC for sea level rise scenarios to be used in other models (DSM2, CALSIM II, CALVIN)
  - G-model
  - ANN

Climate Team Work Plan



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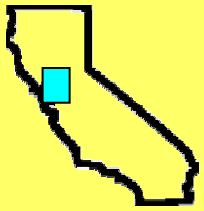
Investigate water supply impacts of hydrology changes



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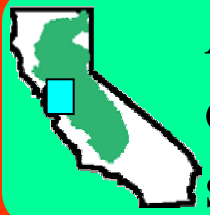


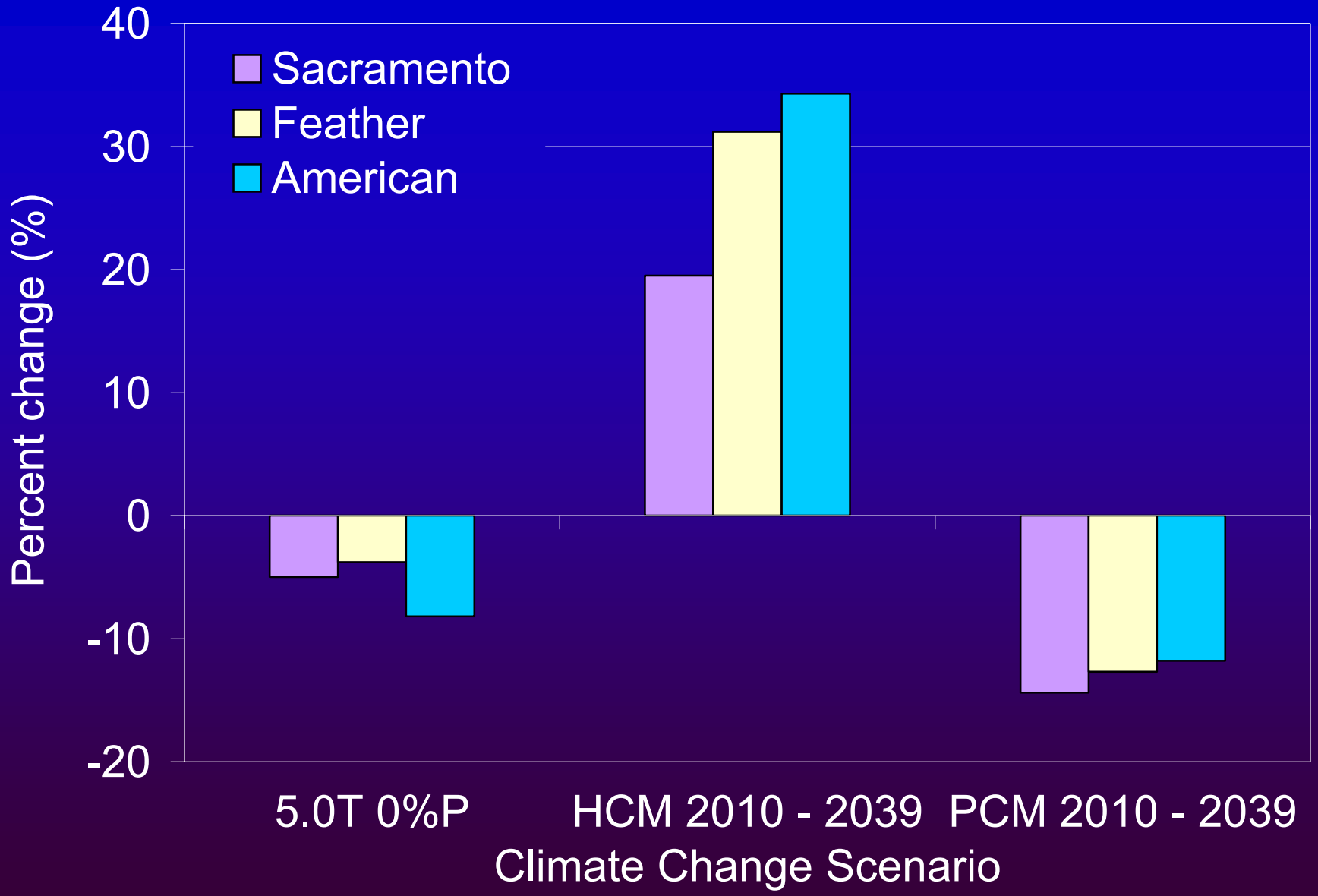
Assess combined impacts of changed hydrology and sea level rise

Work Plan 2003-04 Time Line

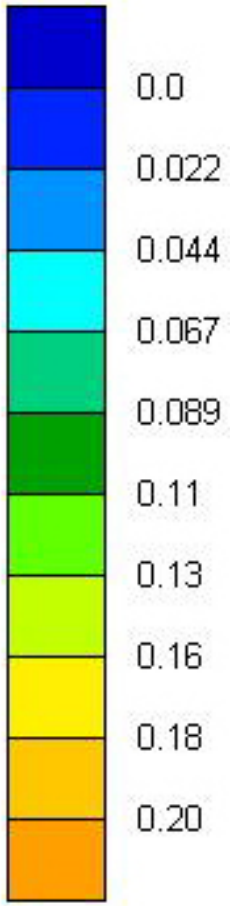
	OND 03	JFM 04	AMJ 04	JAS 04	OND 04
Refine work plan					
Uncertainty analysis					
First cut analysis and simulations					
Refined analysis and simulations					
Document findings					

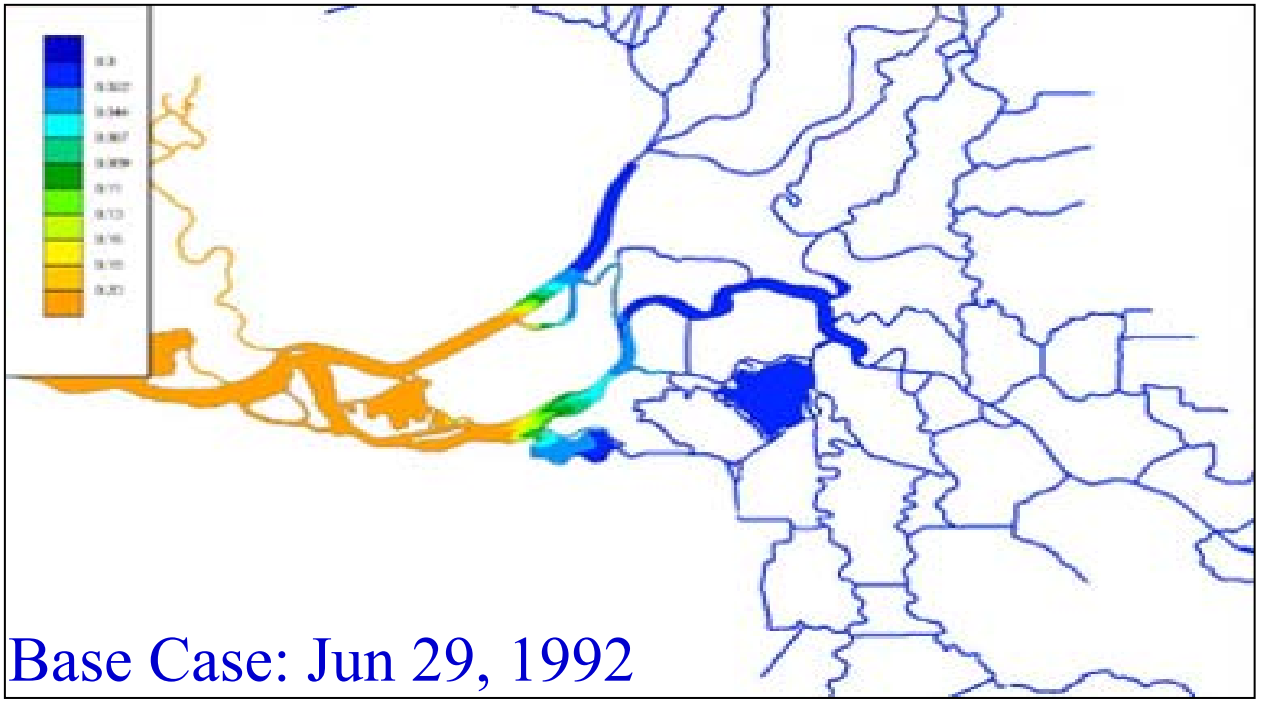
One of our long term goals: provide info for 2008 CA Water Plan update

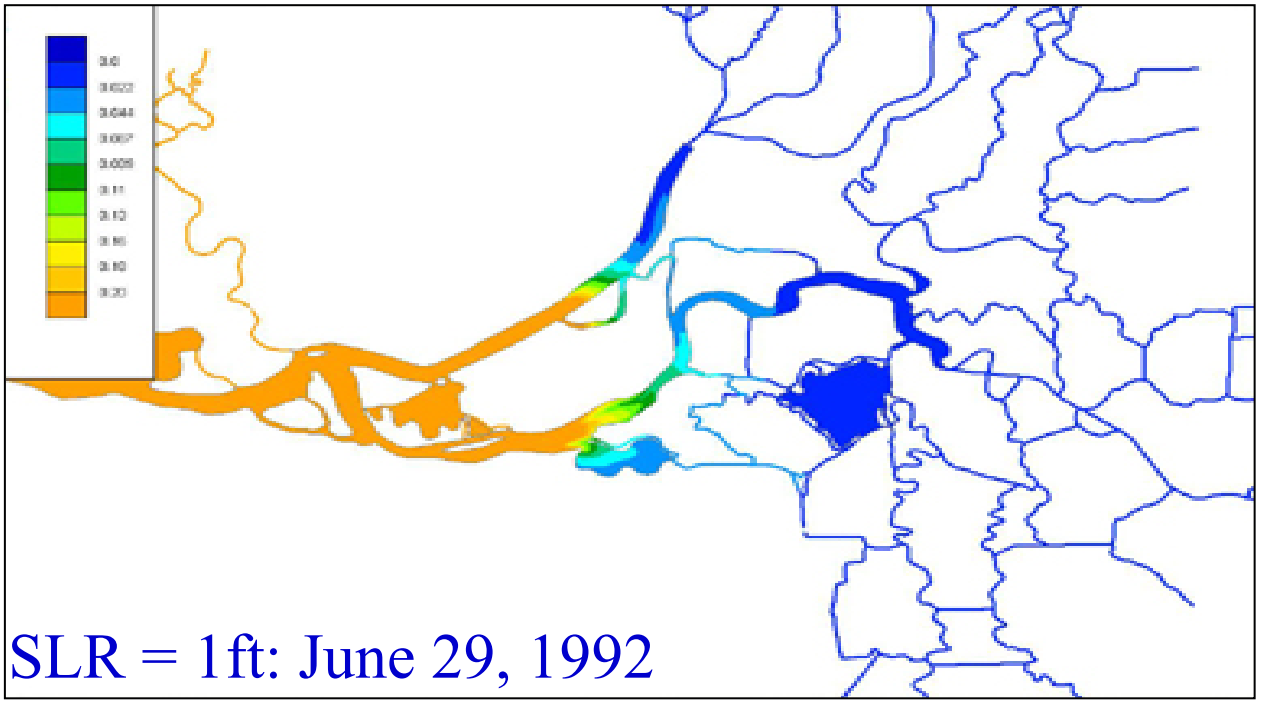
Average Percent Annual Change of Index Basin Runoff Compared with Historical Data (1963-1992)



Simulated Salinity Intrusion TDS

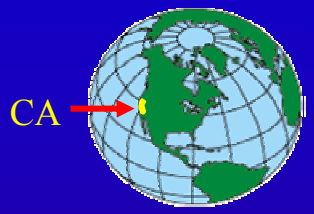






Relationship between Model Outputs

Global Climate Models



Output
- Precipitation
- Snowmelt
- Air Temperature
- Evapotranspiration
- Soil Moisture

CALSIM II

Output
- Reservoir operations
- Project deliveries
- Delta inflows and exports

DSM2 or RMA

Output
- Flow
- Stage (water level)
- Salinity
- Other water quality constituents

Outputs shaded blue provide input to the next model.